Flash Memory in Wireless and Portable Information Appliances

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Overview (1)

- Since its first appearance on the market less than 15 years ago, Flash memory has evolved into the non-volatile memory of choice for many applications
- One of the key drivers has been the portable Wireless and Information Appliance market
  - Has become the largest consumer of Flash in $$
  - Manufacturers have enhanced Flash capabilities to address particular requirements of these applications

Overview (2)

- In this session we will examine
  - The market for Flash and what is driving it
  - The applications needs of the portable wireless and Information Appliance market and how Flash manufacturers are addressing them
  - User concerns in selecting a Flash device and supplier for their requirements

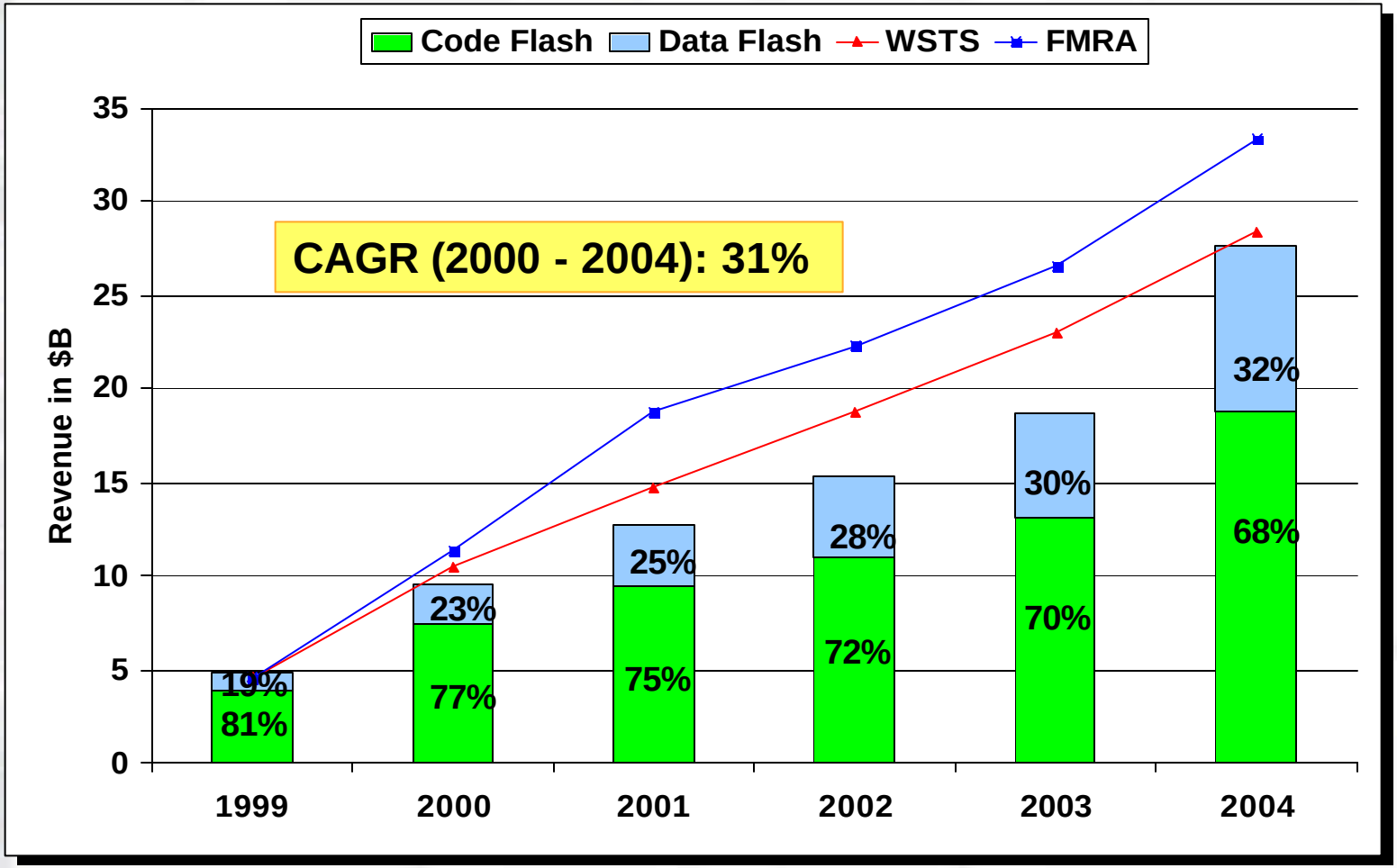
Agenda

- Overview
- Flash Memory Market and Market Trends
- Application Trends
  - Product
  - Flash Memory
    - New Flash Memory Features
- User Concerns
- Summary

Why is Flash Used?

- Non-volatile, solid state, file storage
  - Store Program ✍ Code store or NOR Flash
  - Store Data ✍ Data store or AND/NAND Flash
- Electrically erasable and reprogrammable
  - Simple and fast factory and field code updates
    - In-system remote updates possible
    - Yields manufacturing and inventory efficiencies
- Multiple product versions with a standard hardware platform

Flash Memory Market Forecast



Source:

Bar chart by Hyundai Flash BU based on analyst forecasts

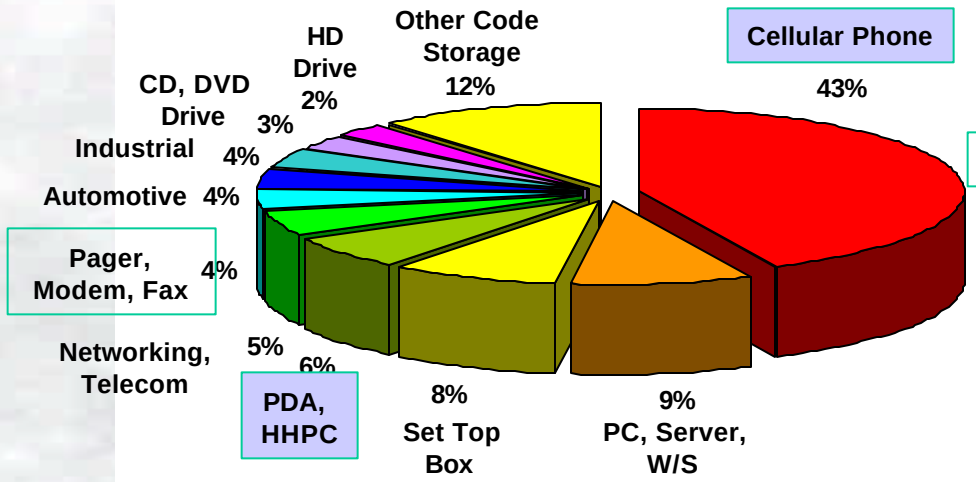
Line charts by Web-Feet Research based on FMRA (Flash Memory Reporting Assoc.) and WSTS (World Semiconductor Trade Statistics actual data. These forecasts include SRAM Portion of Flash/SRAM combo units

Flash Market Segmentation for 2001

Total: $12.7B

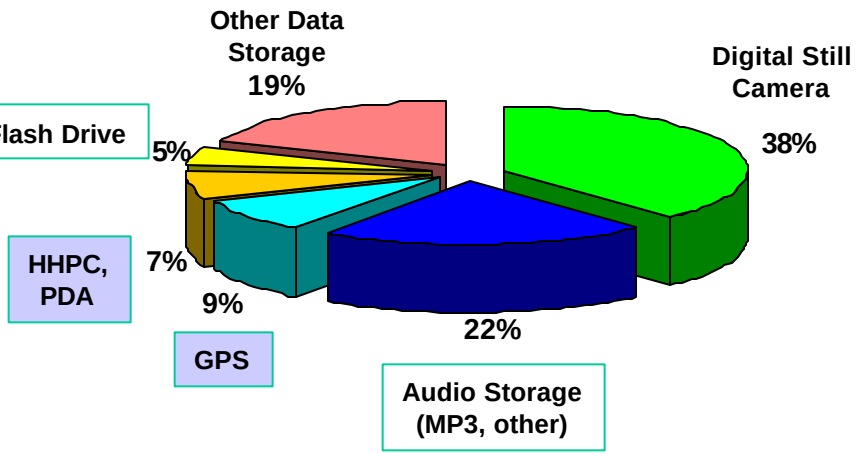
Code Flash

$9.5B (75%)



Data Flash

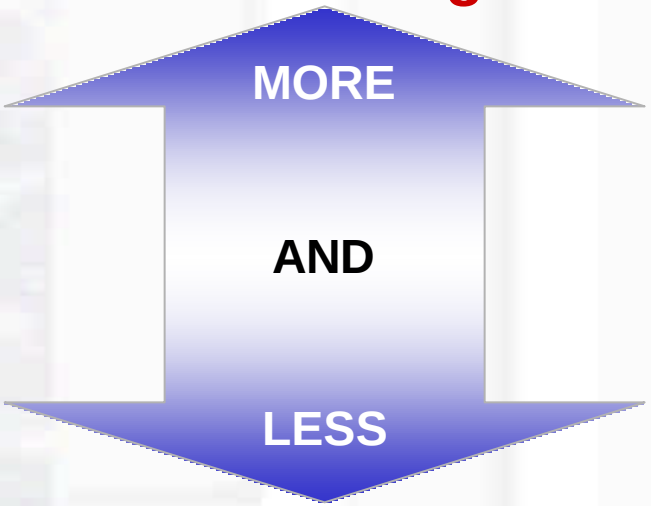
$3.2B (25%)



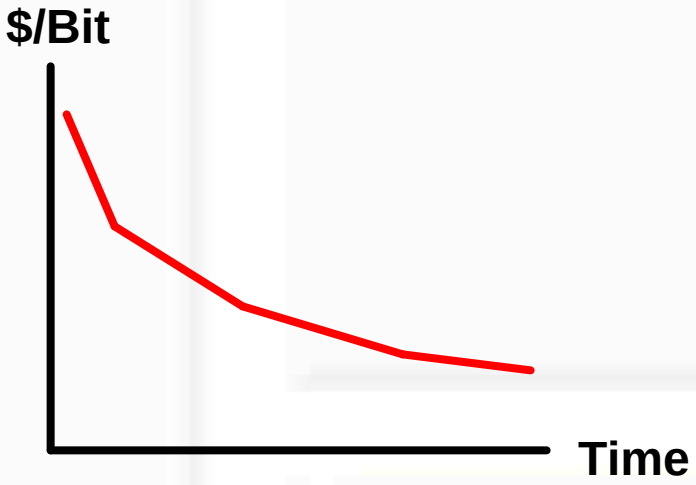
(Source : May `00 WSTS, Hyundai Flash BU)

Some Key Factors Driving Flash Market Growth

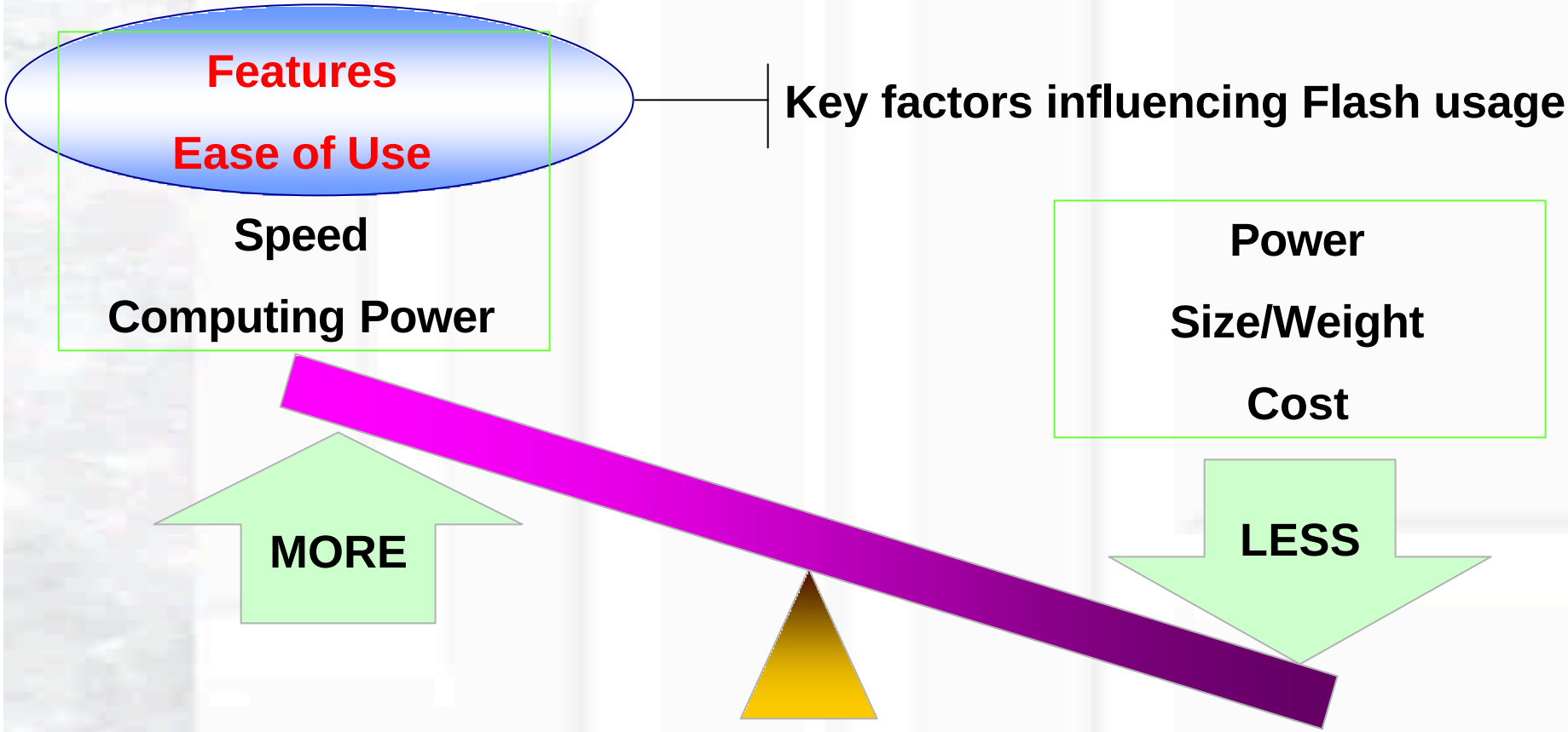
Customers are demanding:



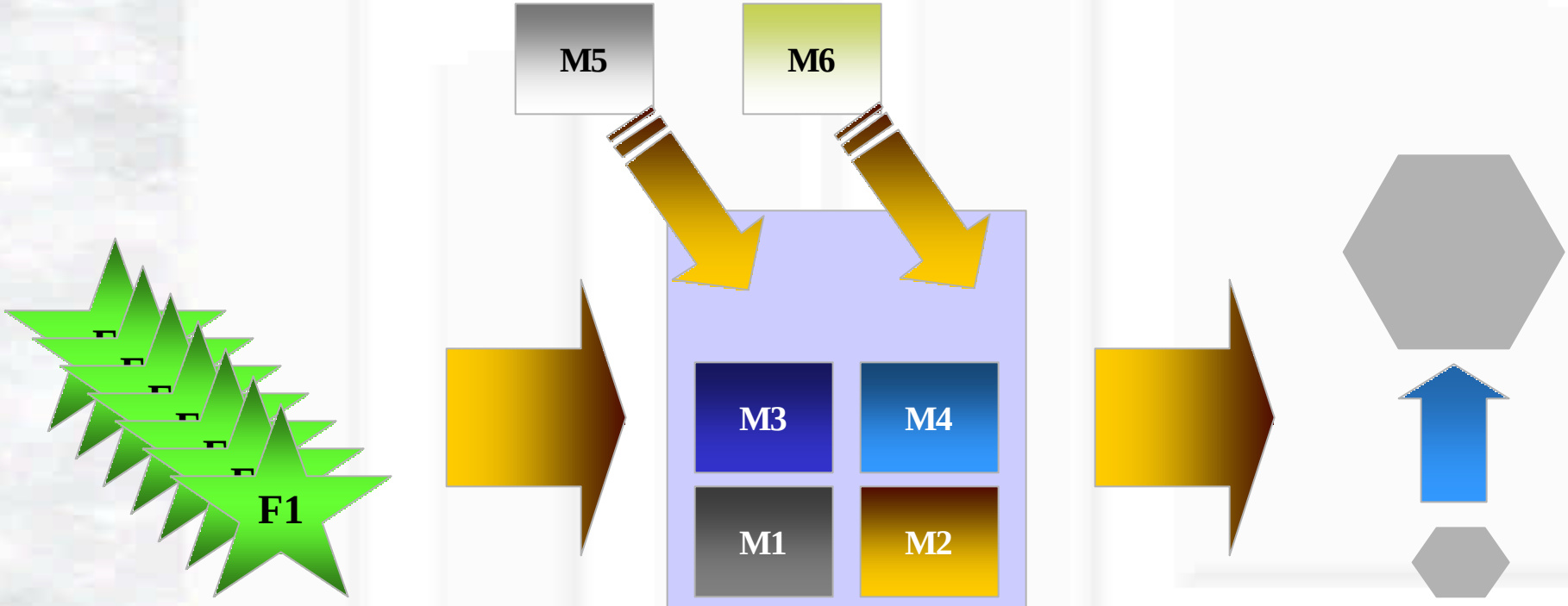
Flash cost/bit is decreasing rapidly



Customers are Demanding More . . . and Less!!

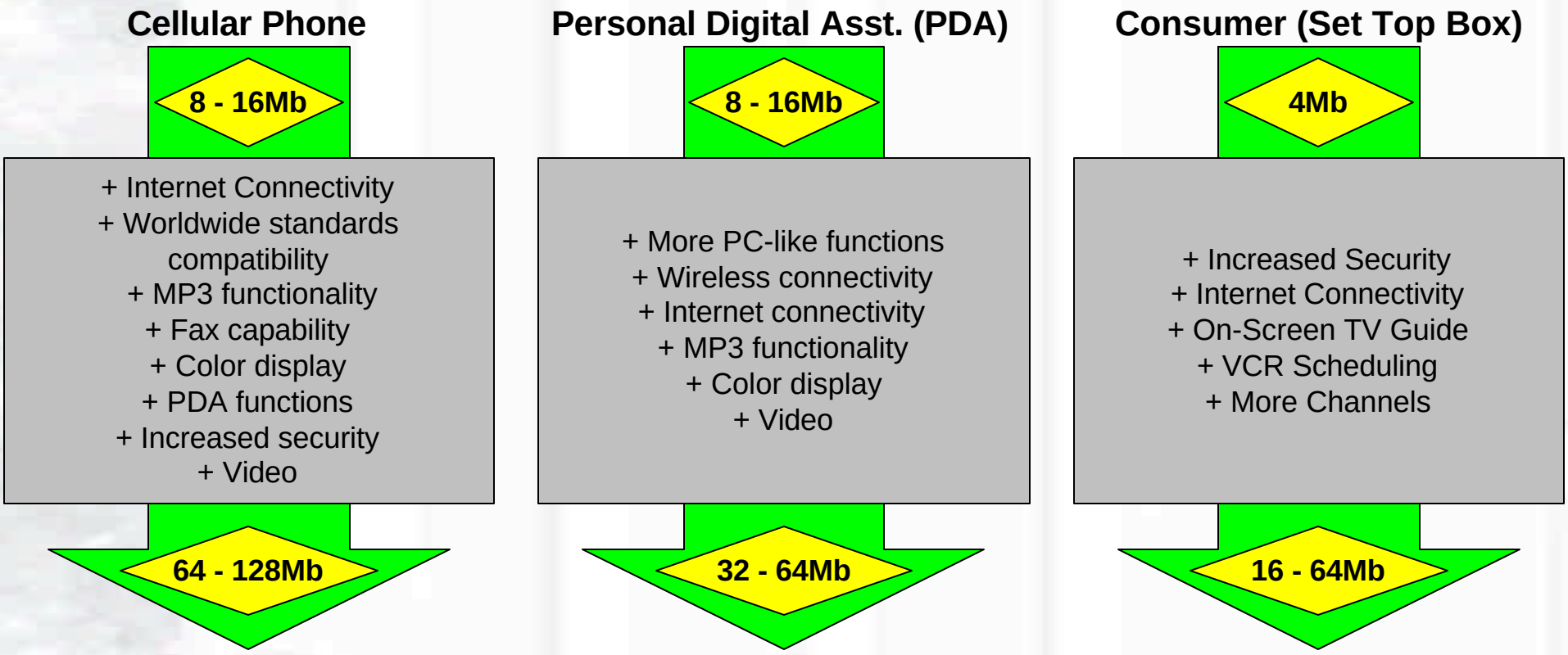


Features Translate to More Flash



MORE FEATURES = MORE FIRMWARE MODULES = MORE FLASH!!!

Some Examples of Flash Requirement Growth



= Typical Flash Memory Requirement

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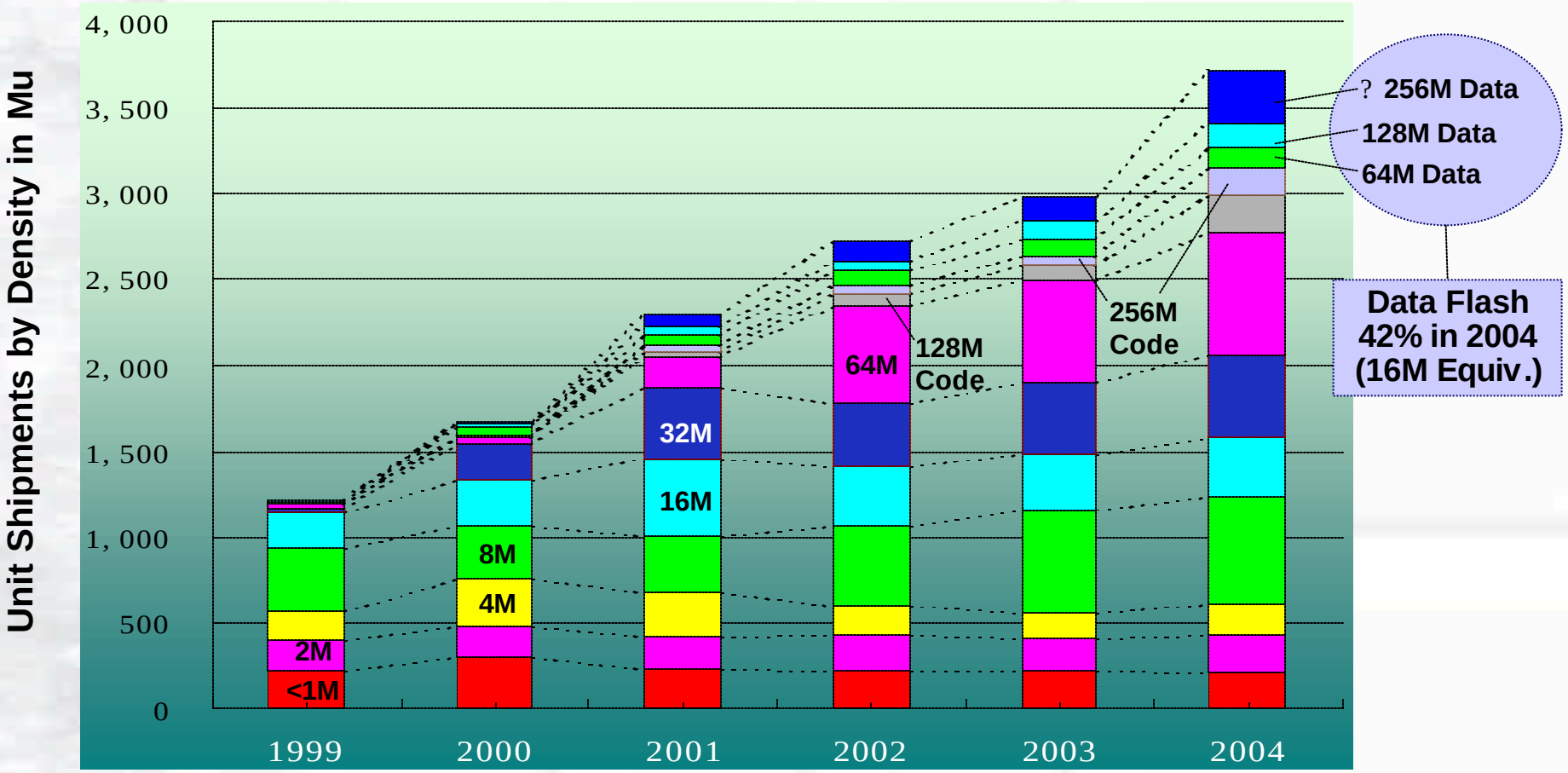
Flash Unit Forecast by Density

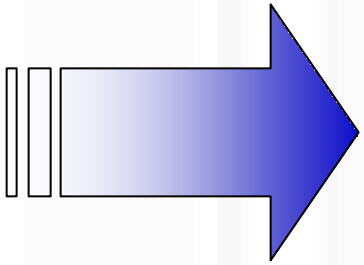


(Source: Semico June 2000 and Hyundai + Flash BU)

Lower Cost/Bit ✍ New Applications

- The decreasing cost of Flash has enabled a new class of applications which could not have been economically viable previously
  - The most significant of these is the ‘Digital Consumer Market’, which includes many of the ‘Wireless and Information Appliance’ products

Lower Cost/Bit ✍ New Applications



Emergence of "Digital Consumer" Market

Cellular Phone

MP3 Player

Organizer

PDA

Digital Camera

Voice Recorder

DVD Player

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    - New Flash Memory Features
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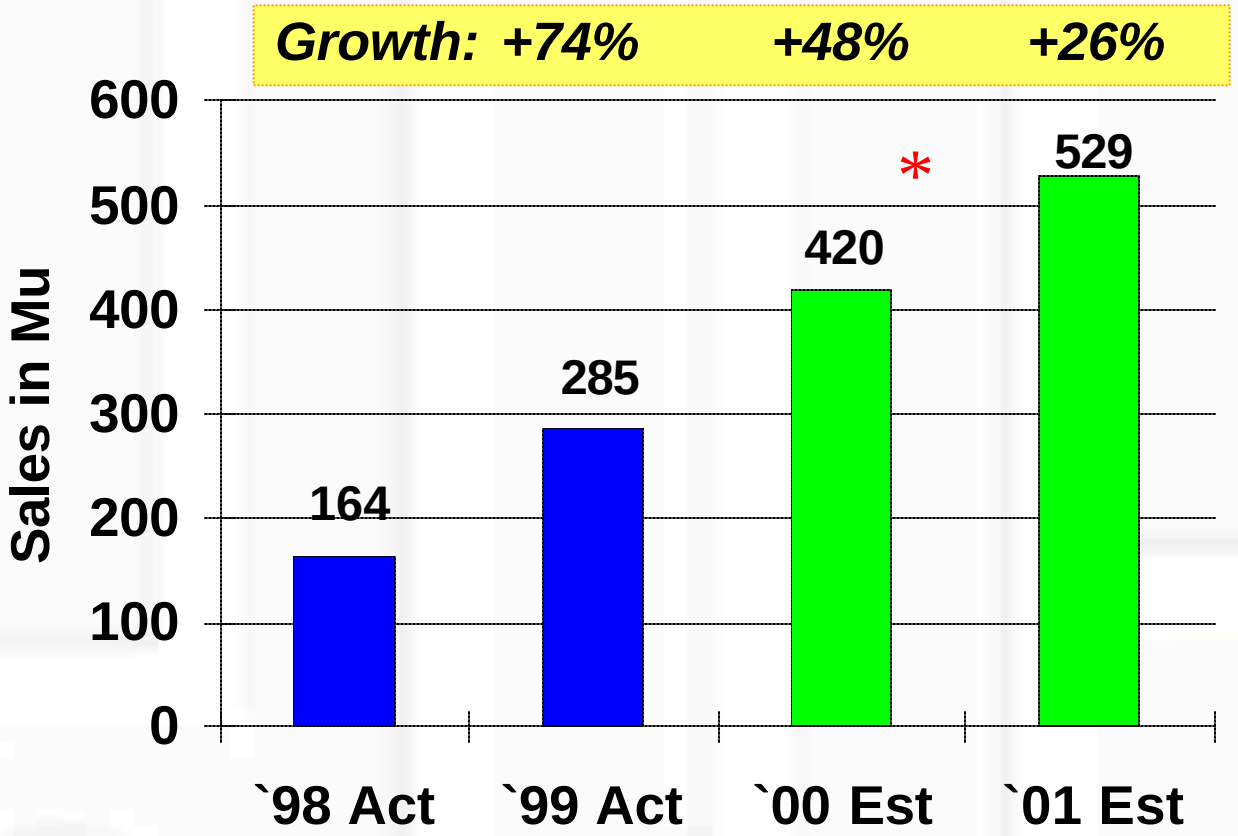
Convergence of Phone and Portable IA Functions

- Many Information Appliances are becoming phone-enabled
- At the same time, cellular phones are becoming ‘smarter’ by adopting a number of Information Appliance functions
- Thus, we can expect that many of the trends observed in the more mature cellular market will apply to the portable IA market as well

Trend - Rapid Market Growth

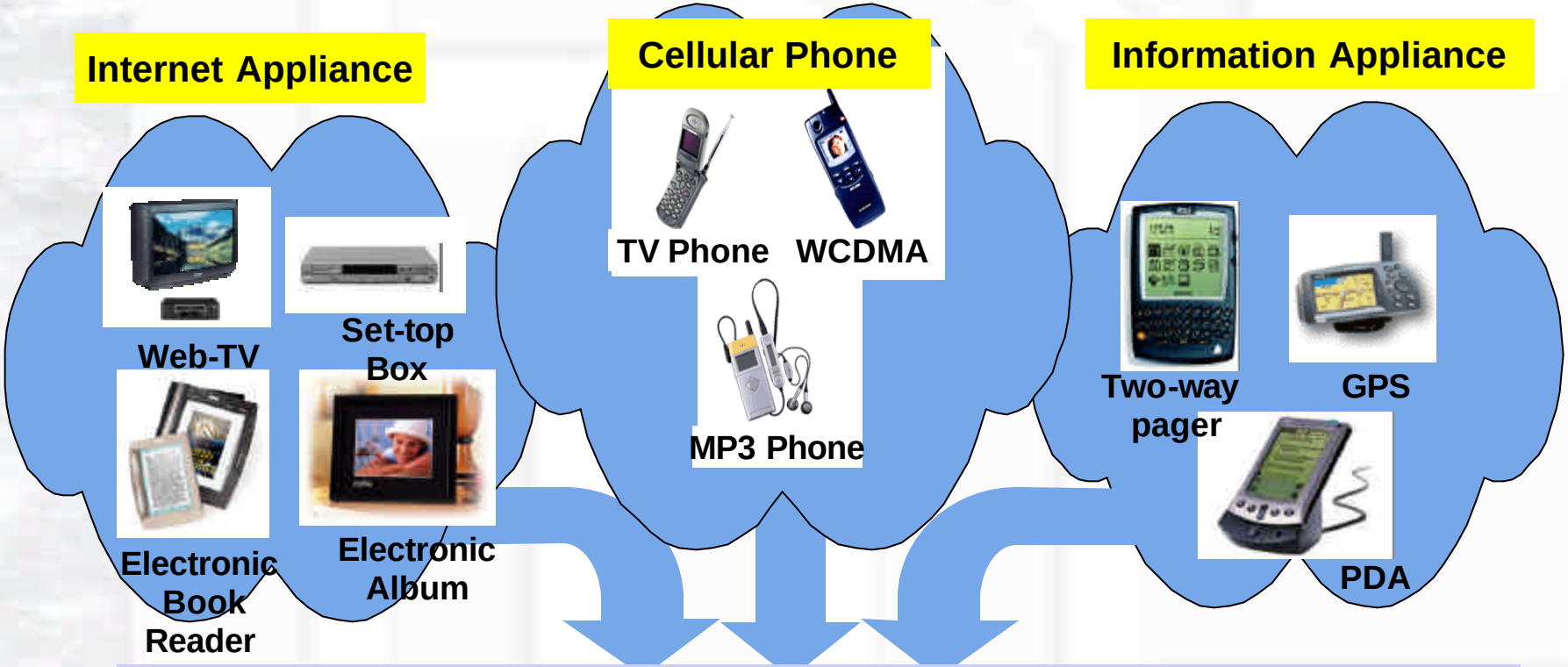
e.g., Cellular Handset Unit Sales Forecast



Source : Dataquest

* Note: Nokia estimated that 405 million handset were sold WW last year

Application Requirements for Flash



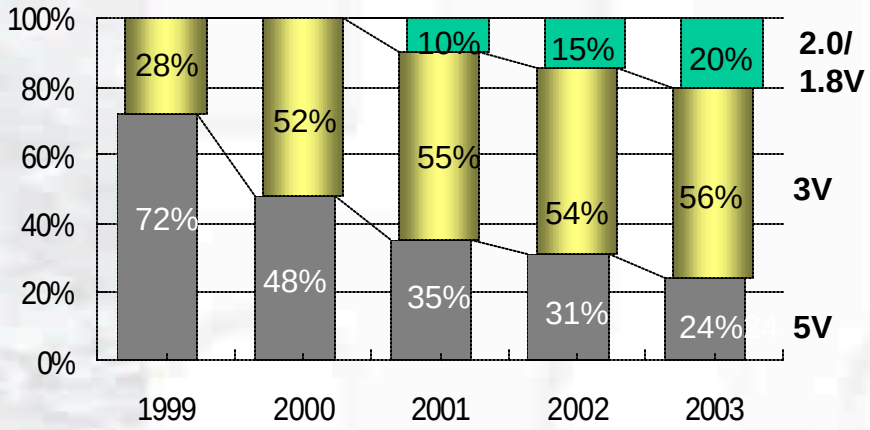
- Code and Data storage ✍ NOR and NAND Flash
- Wireless/Portable ✍ Low power consumption
- Graphics support, complex algorithms ✍ High performance
- Small form factor ✍ Small packages (CSP and MCP)
- Security ✍ Anti-cloning features

Flash Trends in Wireless and IA (1)

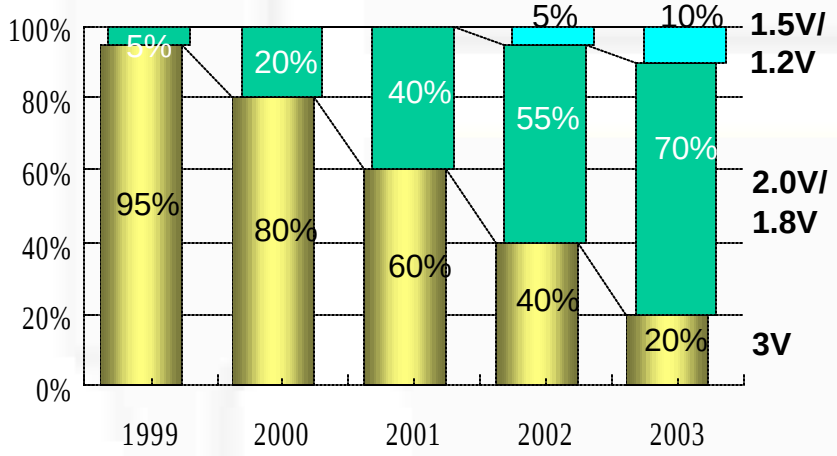
- In portable applications in particular, require-ments for extended operating life and smaller form factor (smaller battery) will drive a continuing reduction in operating voltage

Code Flash Operating Voltage Trend (in units)

Non-Cellular Phone



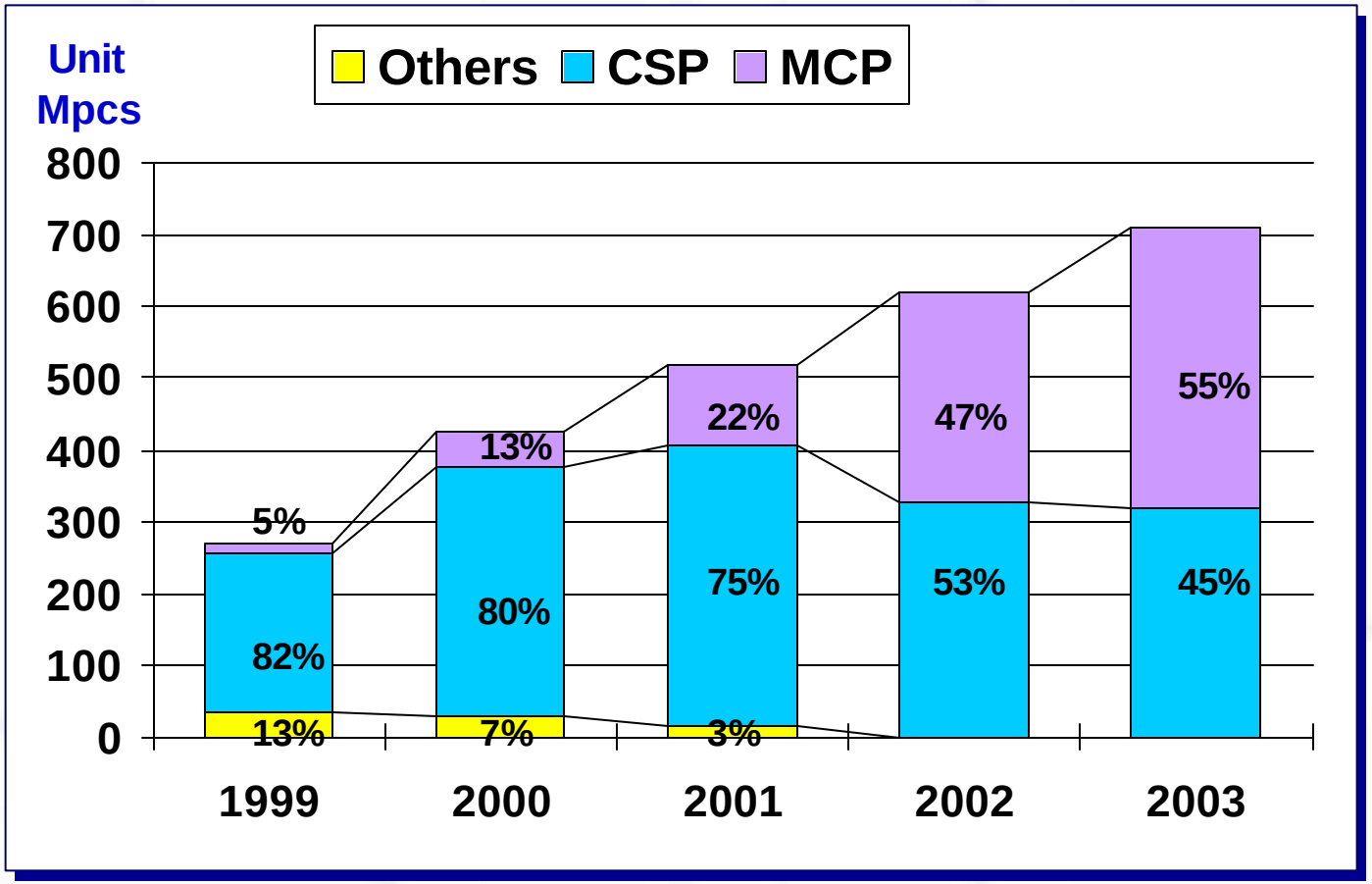
Cellular Phone



Flash Trends in Wireless and IA (2)

- Flash will be utilized in various form factors, depending on size and user interface requirements
  - Component
  - Combo Chip
    - [Code Flash/SRAM], [Data Flash/SRAM], [Flash/DRAM]
  - Card
    - Memory Stick, PC Card, CompactFlash Card, Multi-Media Card

Flash Memory (Cellular Phone) Package Trend



CSP = Chip-Scale Package, e.g., FBGA, µBGA

MCP = Multi-Chip Package, e.g. Flash + SRAM

Same Application, Different Devices

e.g., Products Used by Key Cellular Phone OEMs in 2001

Products \ Customers		A	B	C	D	E	F	G	H
16M	3V Standard		✍	✍	✍	✍	✍		
	1.8V Dual Bank				✍	✍			
	3V Dual Bank				✍	✍			
32M	1.8V Dual Bank			✍	✍	✍			✍
	1.8V Dual Bank with Burst Mode		✍			✍			
	1.8V Dual Bank Burst + Mux A/D	✍							
64M	1.8V Dual Bank			✍				✍	
	1.8V Dual Bank with Burst Mode		✍					✍	
	1.8V Dual Bank Burst + Mux A/D	✍							
Software RWWE		Some customers use software instead of Dual Bank for RWWE capability							

✍ : Major component in 2001 (Customer Input)

✍ : Major component in 2001 (Hyundai forecast)

✍ : Minor component in 2001 (Hyundai forecast)

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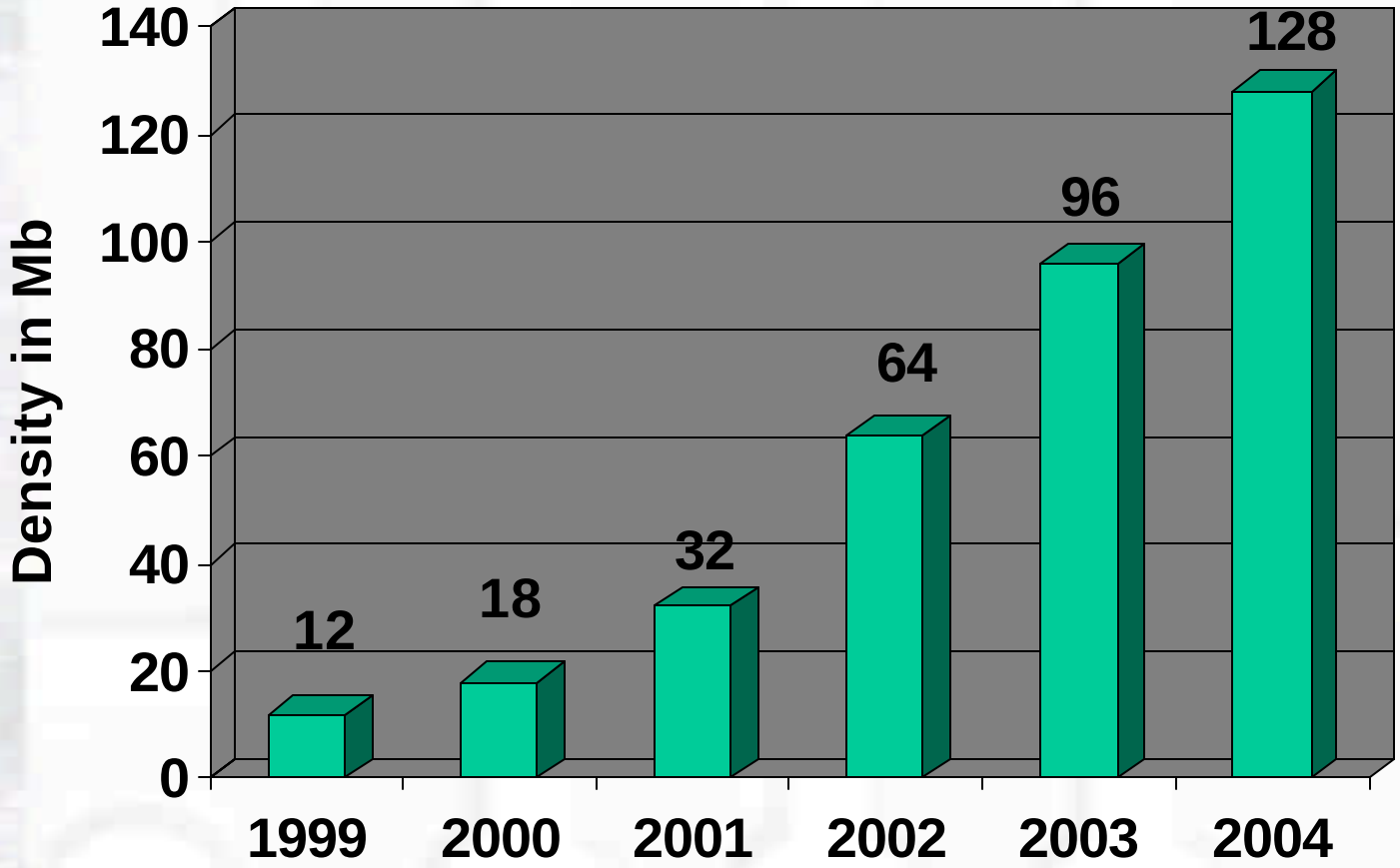
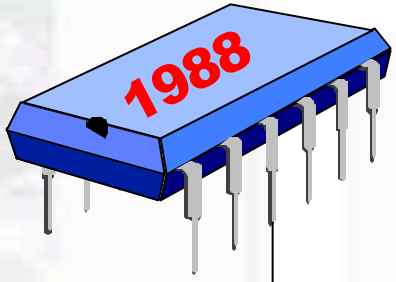
Flash Trends in Wireless and IA (3)

- As more features are added and the cellular and IA functions converge, an increasing amount of firmware will be required
  - Average Flash density will increase dramatically
  - Some changes in the traditional memory architecture will evolve

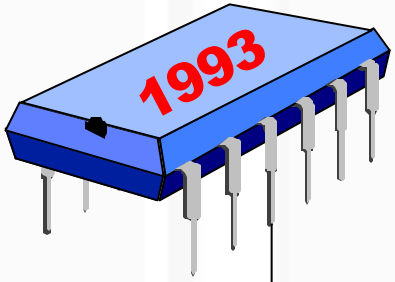
Projected Flash Average Density in Smart Cellular Phones



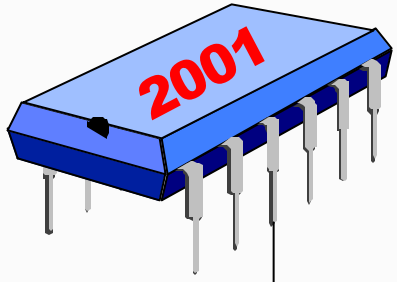
Flash Memory Evolution



- Dual supply
- Bulk erase
- ROM/EPROM replacement

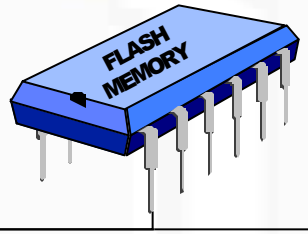


- Single supply
- Sector erase and protect
- In-system programmability



- Code store and data store versions
- Low voltage operation
- Page and burst modes
- Simultaneous R/W (RWWE)
- Common Flash Interface (CFI)
- Security features
- Accelerated programming
- Fast erase
- Chip-scale packages
- Flash/SRAM combo chips

Two Major Flash Memory Types



Program Store
(NOR Architecture)

- Store program for a uP
- Store small amounts of data
- Fast random access
- Sector erase, byte/word program

Some Typical Applications
- Cellular phone
- PDA, Organizer
- Set-top box
- DVD
- Networking equipment

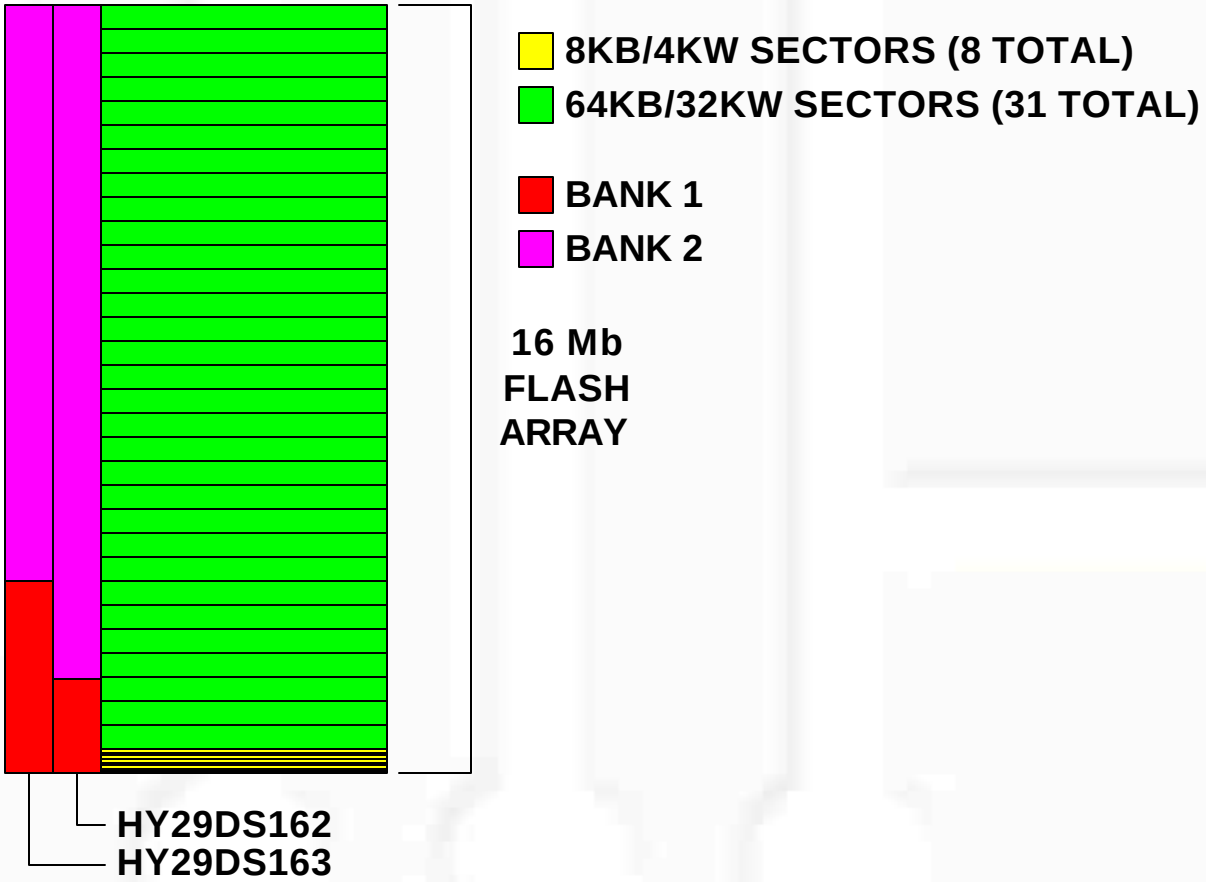
Data Store
(AND/NAND Architecture)

- Store large amounts of data
- Slow random access
- Fast serial access
- Page erase and program
- Lowest cost/bit

Some Typical Applications
- Solid-state disk
- Digital camera
- MP3 player
- Voice recorder
- GPS Navigation Computer

Simultaneous Read/Write Operation

- Flash array is divided into two or more ‘banks’ of sectors



Simultaneous Read/Write Operation

- Host reads from one bank while a write or erase takes place in any other (RWWE)
  - Thus, program can continue to be executed from one bank while data is being modified in another
  - This capability requires two devices with conventional Flash, or requires OS to be downloaded to another memory
- Reduces system complexity and cost
- A software solution is possible (e.g., FDI) but requires complex software and special Flash device features

Security Enhancement Features

- Intended to provide fraud protection for certain types of equipment such as cellular phones and set-top boxes
- Two examples
  - Security Sector: AMD (SecSi), Hyundai (Sec^2)
  - Protection Register: Intel

Security Sector

- An extra sector outside the normal array that can be factory locked and confirmed
  - A portion is used for a factory-programmed Serial Number, then the sector is factory locked
  - A ‘Factory Lock’ indicator is set by the factory and can be interrogated to ensure that a user programmed device has not been substituted
- Alternatively, the sector can be programmed, read or erased just like other sectors once a special command is given.
  - But in this case, cloning is easily achieved

Protection Register

- An 8-word register that can be read with special commands
  - Four words are reserved for factory programming
    - Cannot be programmed by the end-user
  - The other four words can be programmed and locked by the end-user

Performance Enhancement Features

- Flash technology improvements
  - Smaller device geometry
  - Enhanced interconnect technology
- Fast read access methods
  - Page mode
  - Burst mode

Asynchronous Page Mode Read

- Read cycle retrieves a ‘page’ of words from the array and stores them in a local buffer
  - Page size is typically four to eight words
- Allows rapid asynchronous access to data within a page after the normal initial access delay
- Page data can be read in any order

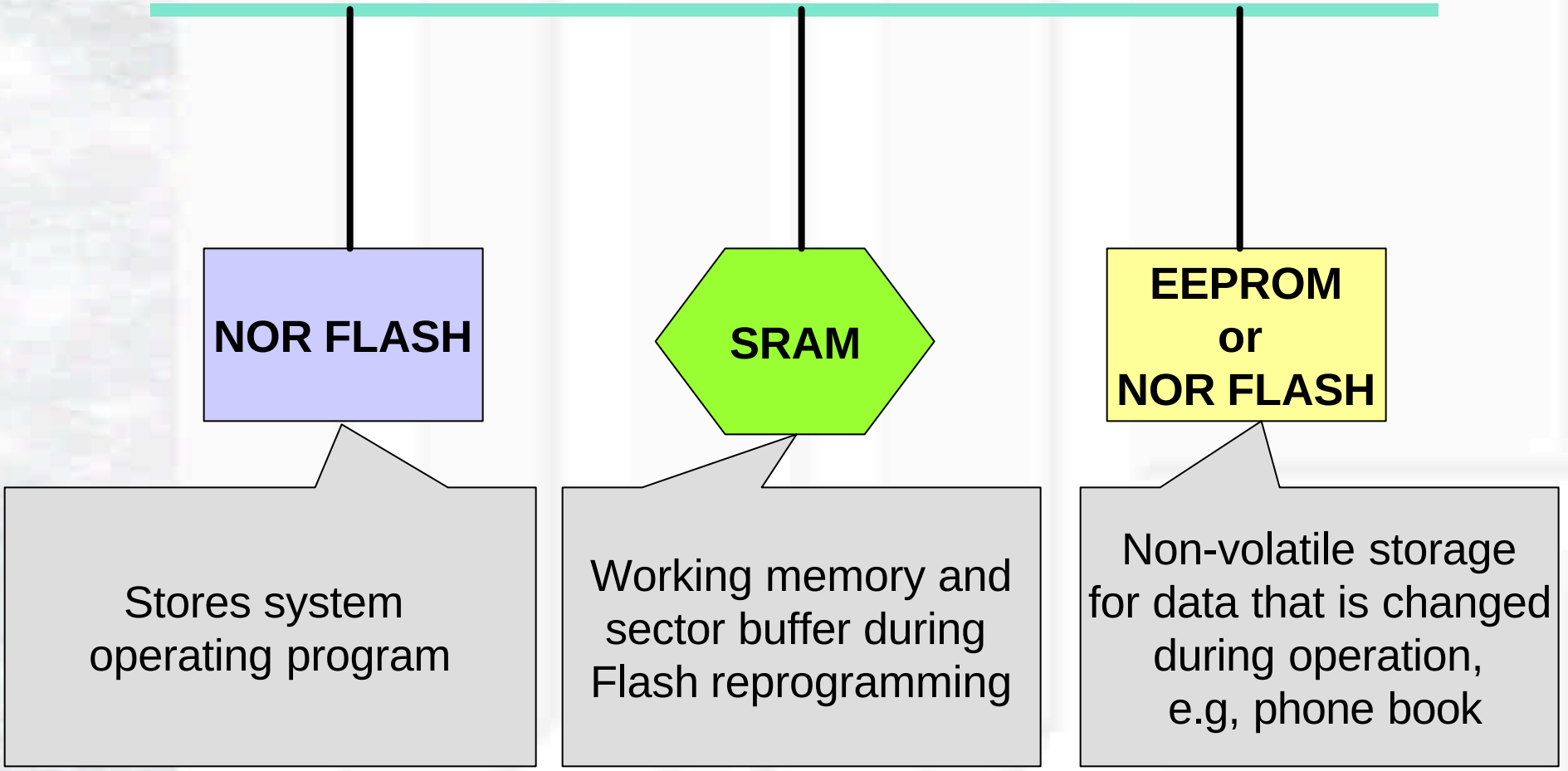
Synchronous Burst Mode Read

- Useful for fast moves of data between Flash and working memory
  - e.g., image files, voice templates
- Provides fast access to Flash array data after the normal initial access time for the first read
  - Output is synchronized to a CLK input signal
- Initial address is provided by the host, subsequent data is accessed sequentially
- Implementation varies amongst suppliers

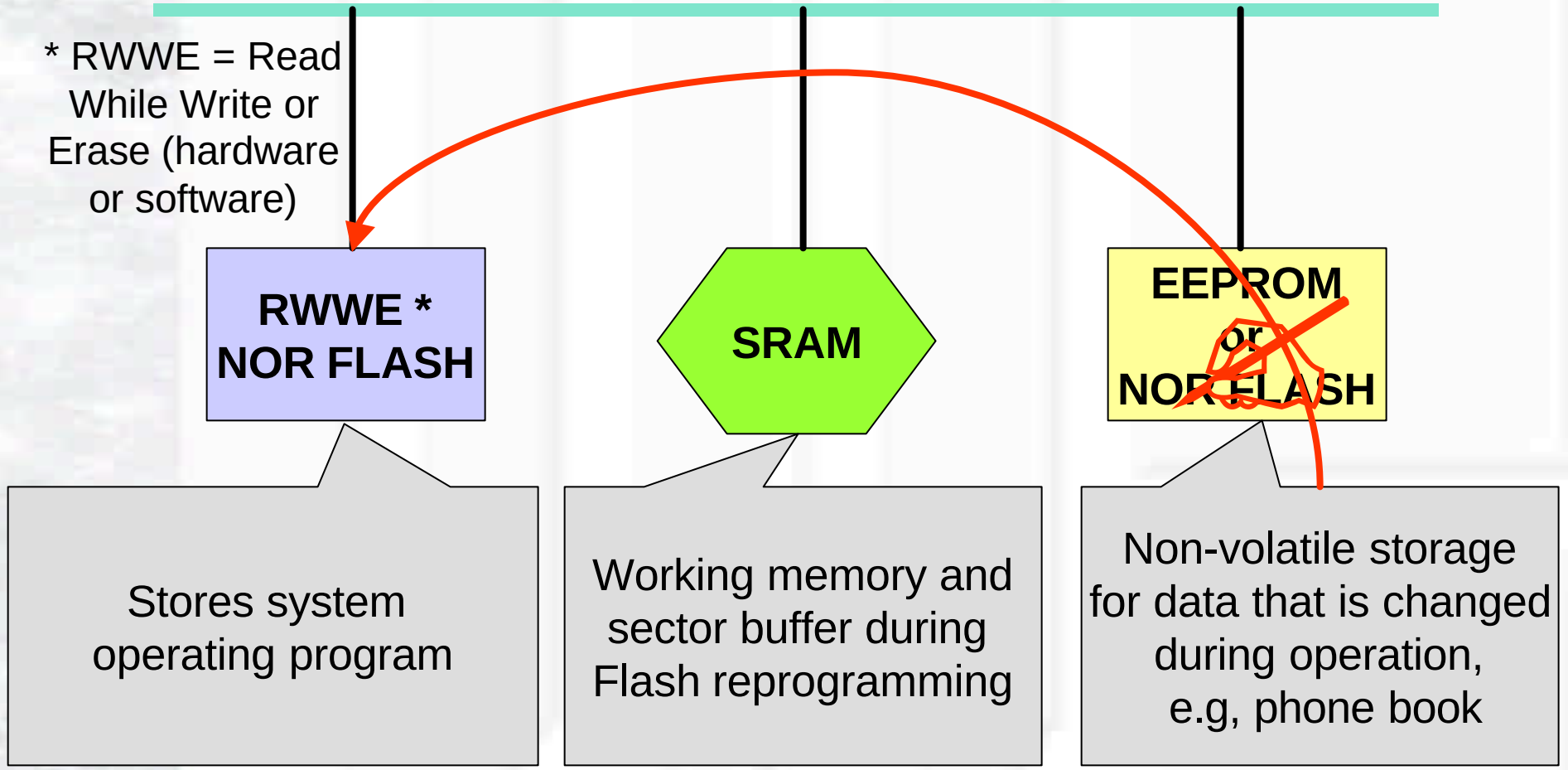
Accelerated Programming

- Intended primarily to speed up Flash device programming in a production environment
  - Requires a high voltage on a designated pin, typically 10 - 12 volts
- Significantly reduces the programming time
  - Typically 40 - 50% programming time reduction
  - Intel offers an additional feature called ‘Enhanced Factory Programming’ that reduces the time by about 60%
    - Available in a limited range of devices

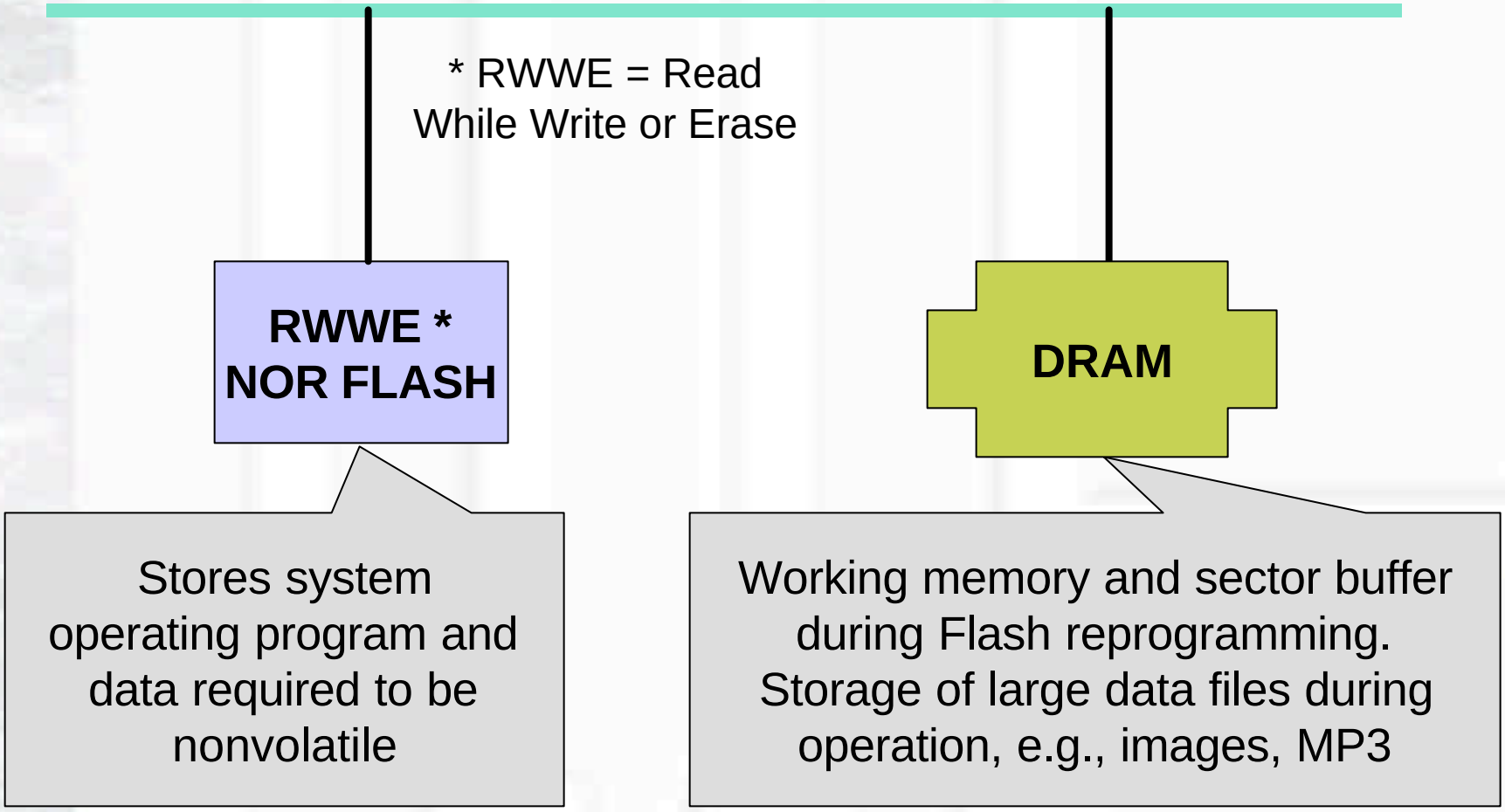
Memory Subsystem Trend (1)



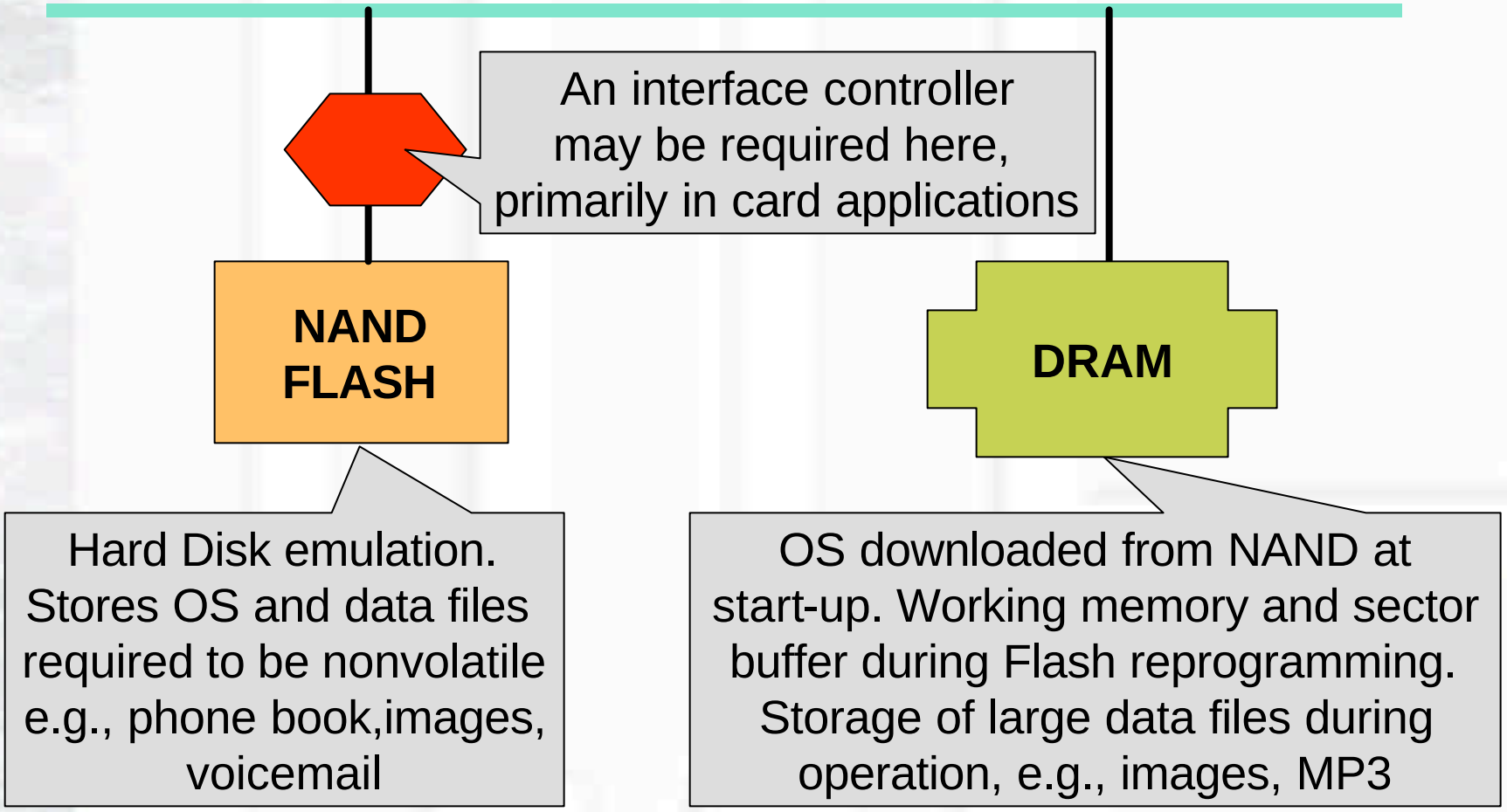
Memory Subsystem Trend (2)



Memory Subsystem Trend (3)



A Possible Future Memory Subsystem Architecture



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- Scope
- Flash Memory Market and Market Trends
- Application Trends
  - Product
  - Flash Memory
    - New Flash Memory Features
- User Concerns
- Summary

Some Major User Concerns

- Second/Alternate Sourcing
  - Items that must be considered
    - Features
    - Command sets
    - Package/Pinout
    - Electronic ID
- Availability

Compatibility Issues - Features

- Feature sets of early Flash devices were the same
  - However some details (e.g., sector architectures) differed
- As manufacturers have added features to their products, the implementations (e.g., burst mode operation) have diverged even further
  - Additionally, the same features may not be available in similar products from different vendors

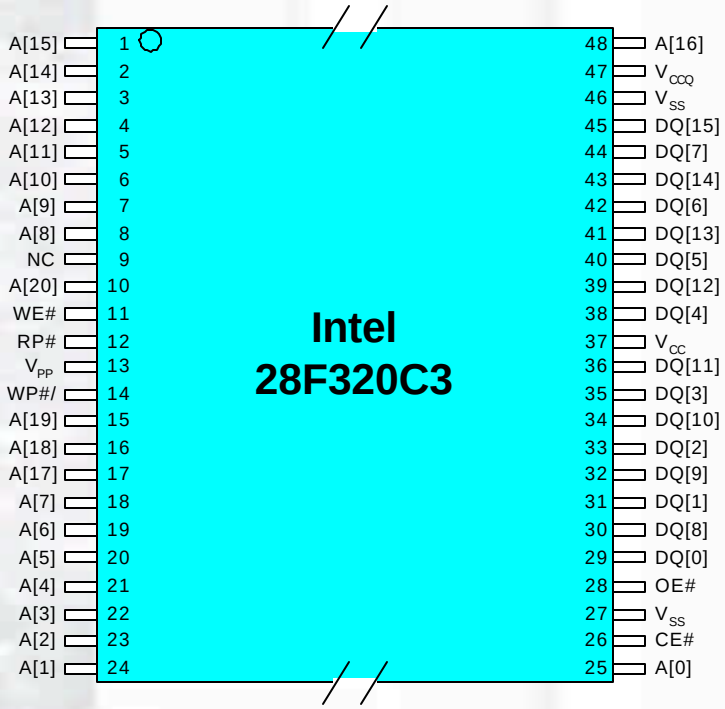
Compatibility Issues - Commands

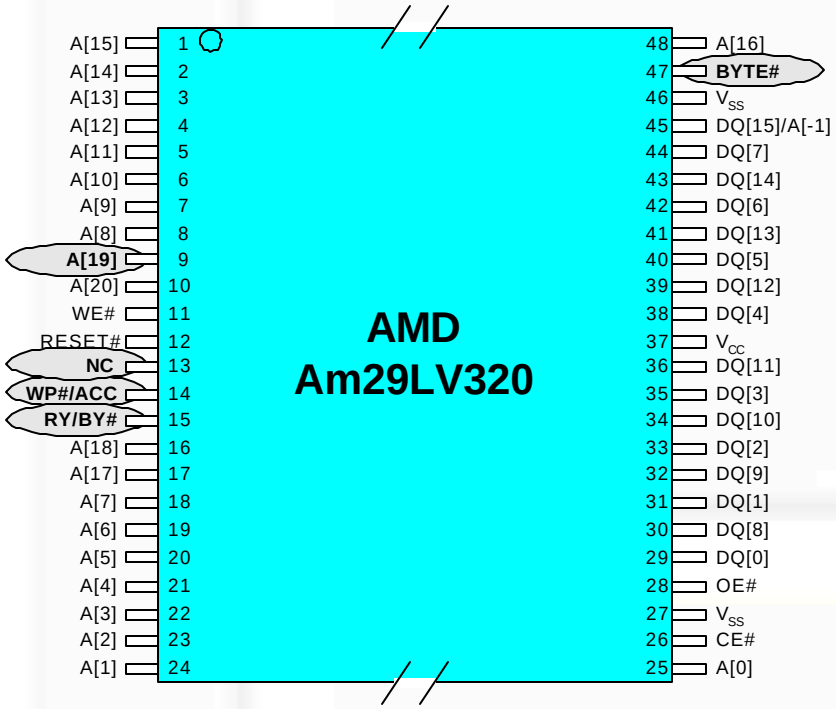
- JEDEC standard provides for two incompatible command sets
  - Dual supply standard: depends on absence of V_{PP} to provide inadvertent write protection
  - Single supply standard: provides that protection through extended command sequences
- Even though virtually all Flash today is single supply capable, some products continue to use the dual-supply command sequences
- Thus, incompatibility even for similar products

Package/Pinout Issues

- Products may not be available in the same package from different manufacturers
- Even if a similar product is available in the same package, pinout differences may exist

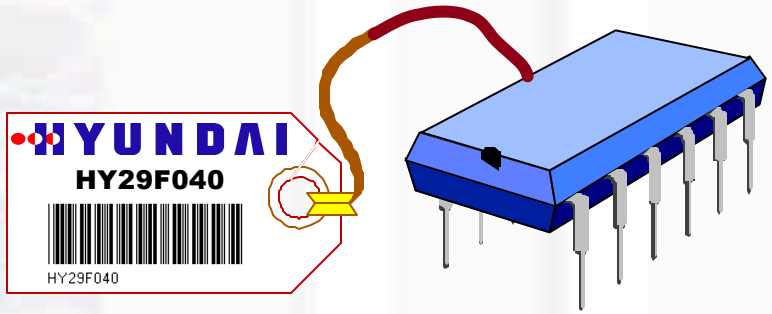
Example: 32M, 3V Devices, TSOP48





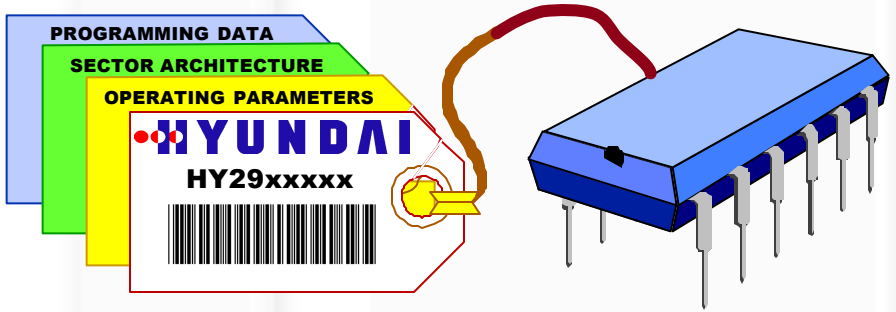
Electronic ID and CFI

Electronic ID



Allows host system to read the device type and manufacturer so that it can select the proper algorithms (erase, program, protect, etc.) for the device.

Common Flash Interface (CFI)



An extension of Electronic ID. Provides additional data, such as operating parameters, sector sizes, some algorithms, etc. A data book on the chip.

Electronic ID Background

- Intended primarily as a means to select algorithms in a device programmer
- Some Flash vendors have encouraged users to include a check for the ID in their designs
  - Limits user's ability to use alternate sources since Electronic ID is unique for each vendor
- CFI is a partial, but not complete, solution

Electronic ID Issues

- Using an Electronic ID test in your software to test that the ‘right’ Flash device is installed will limit your ability to use sources that were not available when the software was written
- Example: ‘F040, 5V, 4Mx8 Flash memory

MANUFACTURER	MFG. ID	DEVICE ID
HYUNDAI	AD	A4
AMD	01	A4
FUJITSU	04	A4
ST MICRO	20	E2
NEW SUPPLIER	????	????

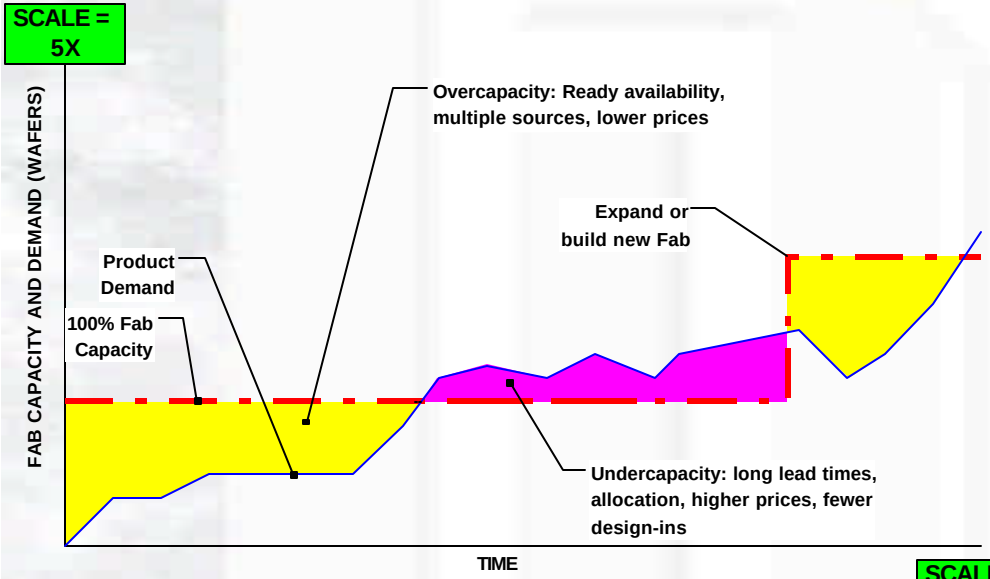
Availability Issues

- A critical issue as products become ‘unique’
- During periods of high demand, such as 2000, most Flash vendors have been unable to rapidly increase their production capacity
- Why?? -- most vendors utilize a dedicated Flash manufacturing facility
  - Requires that a new fab be constructed or a logic/uP fab to be upgraded to increase production significantly
  - This is because the Flash technology is very different than logic or CPU processes

Key Benefits of DRAM/Flash Fab

- Ability to rapidly switch capacity from DRAM to Flash
  - Virtually unlimited Flash capacity
  - Respond rapidly to changes in customer demand
- Rapid ramp up on new Flash process
  - Most fab modules are identical
  - Capitalize on DRAM learning experience
- Low wafer cost resulting from use of fully depreciated DRAM fab

Flash Demand/Supply Scenarios

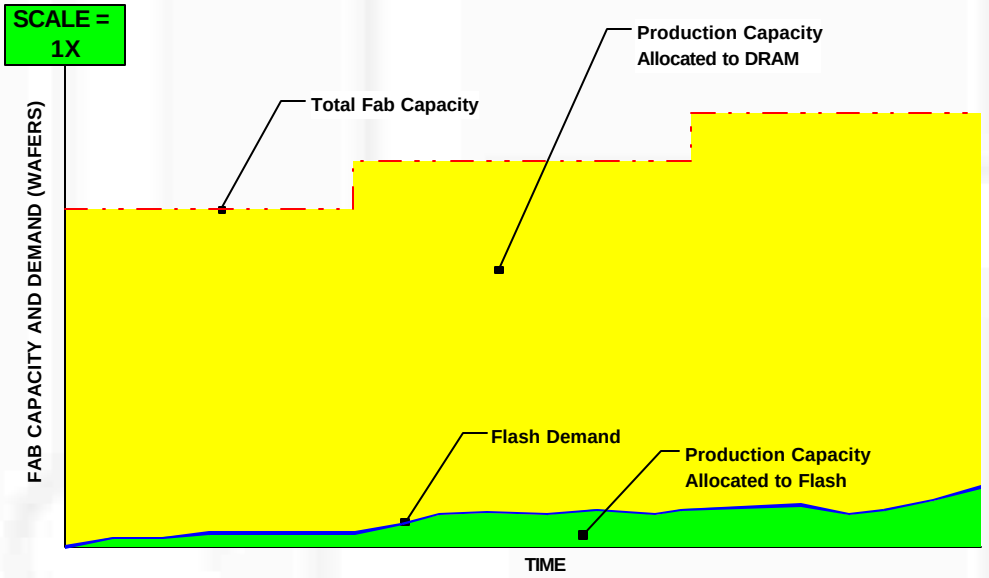


Dedicated Flash Fab

Typical of virtually all current suppliers - slow reaction to changes in product demand

DRAM Compatible Fab

Flash/DRAM production allocation can be adjusted quickly to satisfy changes in product demand



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Summary (1)

- Flash memory has many attributes that make it the non-volatile memory of choice for cellular phone and Information Appliance applications
- The decreasing cost/bit of Flash has enabled many IA products that would not have been economically viable, or even possible, with other types of non-volatile memory
- Cellular and IA are the largest users of Flash memories

Summary (2)

- Manufacturers of Flash have responded to the needs of IA product designers by developing new products targeted specifically for this market
  - Second sourcing has become difficult because of the divergence of feature sets and other product attributes between Flash manufacturers
  - Designers must select products and vendors carefully and may have to make special provisions to ensure that volume needs can be met